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Sustainability of dams on river Alaknanda

Dr. Rajesh Kumari

Abstract

The Indian Himalayan region is abode of three major river systems *viz* Indus, Ganga and Brahmaputra river system. These river systems provides with large volumes of water. This large volume of water has harnessed the present basic needs like availing water for the irrigation, domestic, industrial purpose and for the development of hydropower potential. The development of dams serves as a basic tool for properly channelizing these basic needs. Based on the importance of development of dams, the sustainability of construction of dams on the river Alaknanda has been analysed in this paper. River Alaknanda is one of the two head streams with river Bhagirathi which joins together at Devparyag in Uttrakhand forming the river Ganga. The river Alaknanda basin consists 82.2% of the area to be mountainous ranging between 1000 to 4000 m above sea level. These mountains consists three tectonically separable major litho-stratgraphical units known as Dudhatoli group, the Garhwal group and the Central Crystaline group. The Garhwal group consists of several shear and fracture zones which makes these region fragile to hold the large dams. The development of dams in the fragile and geo-dynamically sensitive zones will result in increased landslides, drying of the river or floods. In return it will result in ecological disturbances, loss of biodiversity, loss of productive lands, damage to forests, social and cultural change, change in socioeconomic status, etc. Thus this study focuses on the sustainability of construction of dams on river Alaknanda by analysing dams being built on river Alaknanda. Measures for sustainable development of dams should be taken care for constructing dams in Himalayan region.

Keywords: Indian Himalayan region, dams, sustainability, river Alaknanda, Garhwal group

Introduction

The Indian Himalayan Region with its major river systems has vast potential for hydropower development. Recognizing this potential, the Government of India in its recent initiative for 50,000 MW power generations proposes to develop several hydropower projects in the Indian Himalayan Region (Agrawal, Lodhi and Panwar, 2010) [1]. Based on the understanding of the prevailing policy framework of the country for hydropower development. The Uttarakhand catchment is endowed with vast hydropower potential, as per Central Electronic Authority Uttrakands potential is of 18175MW hydropower (THDC India Limited, 2009) [18]. Thus for development of hydrel power plants Dams are also built, these dams serves a major purpose for development of this region. But the question arises are these dams sustainable in this region which is tectonically active and most commonly prone to seismic activities.

Damming of a river has been called a cataclysmic event in the life of a riverine ecosystem (Gup, 1994) [9]. The hydroelectric projects interrupt and alter the river's important eco logical processes by changing the flow of water, sediment, nutrient, energy and biota. According to the United Nations, 60% of the world's 227 largest rivers are already severely fragmented by dams, diversions and canals, leading to the degradation of ecosystems (World Commission on Dams, 2000) [20].

The present study focuses on the sustainability of construction of Dams on river Alaknanda by analysing the dams being built on river Alaknanda and its consequences. The measures for sustainable development of dams in this region has been suggested.

Study area

Location: The study area includes the River Alaknanda catchment area (fig 1). Alaknanda catchment is located between 30°0′N to 31°0′N and 78°45′E to 80°0′E, covering an area of about 10,882 sq. This catchment area covers the following districts; Chomali, parts of Puria and Tehri districts and fringes of Kumoun Division of Uttrakhand state of India. As the elevation of the study area ranges from 1451 m to 8000 m.

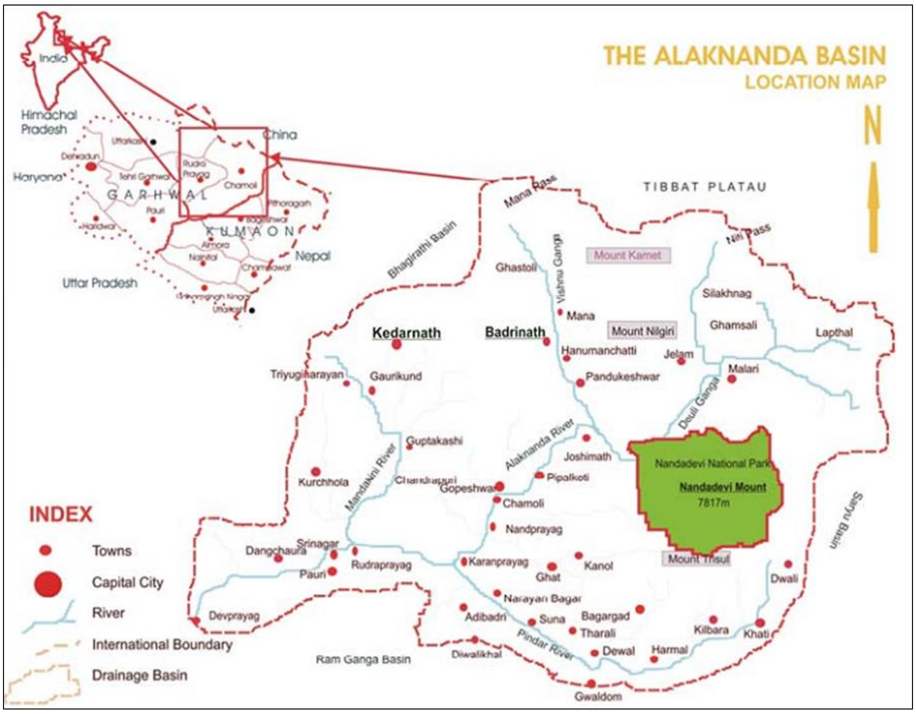

Fig 1: Alaknanda Basin

Geology: The Alaknanda River catchment is underlain by both sedimentary and highly metamorphosed gneissic rocks. In its upper course, the Alaknanda flows through the Central Crystalline zone (Fig. 2.a and Fig 2.b), which is composed of migmatized and granitized Archean metasediments. After passing the Central Crystalline, the river traverses through limestones, marbles and quartzitic sequences of the Tejam and Berinag Formations. Before its confluence with the Bhagirathi, the stream passes through the limestone and dolomite-bearing Uttarkashi Formation and the outcrops of phyllite and micaceous greywackes of the Chandpur Formation. The tributaries of the Alaknanda also flow through a varied terrain of quartzites, limestones, shales and slates.

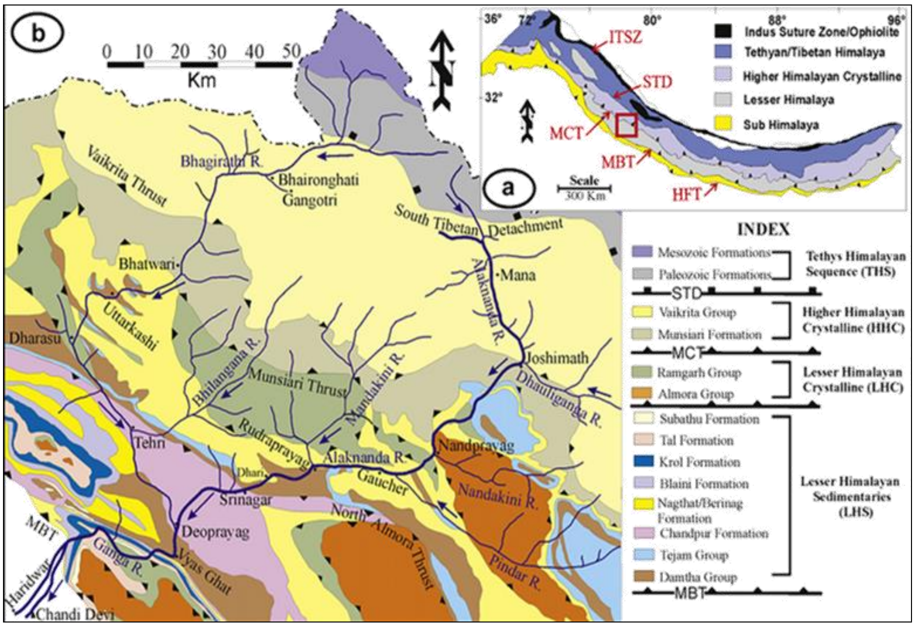

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Fig 2: a) Geological map of the Alaknanda- Ganga river catchment in the Himalaya, b) Geological cross-section as exposed along river

Drainage: River Alaknanda, which originate at an elevation of 3641m from Alkapuri Glacier.

Alkapuri glacier is combination of snout of Bhagirath kharak glacier and Satopath glacier. At Vishnuprayag (1372m) this river is meeting by Dhauliganga which originates near Badrinath peak (3300m). Afterwards Alaknanda flows down through Chomali (914m) confluence with Bhiri), Nandprayag (850m) confluence with Nandakini river(which originates from Nandadevi glacier,6000m), Karanprayag (795m) confluence with the Pindari (which originates from Pindari glacier, 5500m), Rudraprayag (610) confluence with the Mandakini (which originates from Kedarnath glacier, 3700m), and finally to Devprayag (472m) to merge with Bhagirathi river (which originates from Gomuk glacier,3900m) and contributes to the formation Ganga river system. River Alaknanda is approximately 229km in length before its confluence with Bhagirati in Devprayag and its flow of gradient from its origin to Vishnuprayag is 27.54m whereas from Vishnuprayag to Devprayag it flow gradient reduces to 6.93m.

Climate: The altitudinal differences coupled with varied physiography contributes to climatic variations in the Alaknanda basin. The climate varies from sub-tropical to alpine. Despite diverse physiographic characteristics, sub-regional variations in the average seasonal temperature are not striking. Temperature varies from season to season and from valley regions to highly elevated regions as highest temperature is recorded in Srinagar in the month of June (30°C) and lowest in Tungnath in the month of January (0.5°C). The Alaknanda basin receives heavy snowfall about 3-4 months during winter above 2000 m altitudes. Rainfall mostly occurs during monsoon season from June to October. It also varies from the valley regions (low) to highlands (high) and north-facing (leeward) to south-facing (windward) slopes.

Flora and Fauna: The vegetation is dominated by Pinus roxhburghi (1400–700 m), Dalber gia sissoo and Acacia spp. (700 m) and its distribution is governed by the altitude and slope aspect. The Alaknanda valley comprises a highly diversified ecological region since it covers a wide range of climatic conditions under altitudinal variation. Thus, the entire region is provided with a great variety of landscape, which has resulted in diverse flora and fauna. And faunal diversity, the Alaknanda river itself is rich in aquatic diversity. The river sustains about 39 fish species from 15 genera and 5 families. Of these species, 14 are abundant whereas 7 are vulnerable, 15 are at lower risk level and another 2 fall under the endangered category.

Socio-economic profile: District Chamoli is bordered by Tibet in the north - east, district Pithoragarh of Uttarakhand in the north – east, district Uttarkashi in north-west, district Rudraprayag in west, district Bageshwar in south –east and districts Pauri and Almora in south. District is divided into 7 sub-divisions (tehsils) namely Chamoli, Joshimath, Pokhari, Karanprayag, Gair Sain and Tharali. The total population of district Chamoli is 3,70,359 with a sex ratio of 1015. About 86.3% of the total population inhabits the rural areas. Total literacy rate of district is 75.4% with maximum in males. Joshimath is one the largest tehsils of Chamoli district in term of area. It is comprised of 93 villages and 27 notified wards. Total population of tehsil is 39,919 with a sex ratio of 774. Literacy rate of Joshimath tehsil is 78.8%. About 62.7% of the total population is rural.

Cultural setting: The valley is also famous for its mythological importance. There are several heritage sites within the study area like Badrinath Dham, Hemkund Sahib, etc. The holiest of the four main Hindu shrines, 'Badrinath' is situated along the left bank of river Alaknanda. With the splendid Neelkanth mountains as the backdrop, it is an important destination on the sacred itinerary of every devout Hindu, astonishing beauty attracts a large number of tourists every year. In addition, Auli adds to the list of important tourist destinations in the area, which is now popular for snow sports.

Materials and Methods

The Feasibility reports and Environmental Impact Assesment Reports of the hydropower projects being constructed on river Alaknada has been analyzed. The detailed Report of the CEC on Kotlibhel Hydro Electric Project, Uttarkhand has been studied and various other literatures has been analysed based on the field survey of the region has been done.

Analysis

The dams have been constructed to manage the power generation and production of electricity, to create irrigation facility and to store the river water for dry period (World Commission on Dams, 2000). The Hills of Uttrakhand are thirsty and need better water management systems.

Question arises that "is it sustainable to build dams in geo-dynamically sensitive regions."

There are four problems which question marks the sustainability of dams on river Alaknanda

1. Landslides: Landslides occur when hill side or valley side slope falls due to certain geological, climatic and biotic factors (Sandhya, 2012). Geologically the Alaknanda valley consists of three tectonically separable major litho-stratigraphical units- Dudhatoli group, the Garhwal group and the central crystalline group (fig.2.a and fig.2.b). The Garhwal group which is separated by the Main Central Thrust existing in NW-SE direction consists of several shear and fracture zone *viz* Kalliasor, Nandprayag and Belakuchi which have highest frequencies of landslides. The Northern Zone extending from Vishnuprayag to the village Manna and its environs along the river Alaknanda and Dauliganga consists of schist, gneiss and granite of the Central Crystalline Group which rests over the Garhwal Group. All the Thrust Zone have a general trend of NW-SE just parallel to Himalayan ranges, but the Alaknanda river flows in a NE-SW direction. With the result the Thrust faults are lying almost perpendicular to the river Alaknanda (Saxena, 1987). Similar case happens with the tributaries of Alaknanda river joining it almost perpendicularly (ranging from 60° to 90°), thus this area is susceptible to landsliding, which may destroy the dam structure.

Geomorphologically the valley consists of three distinct land forms from high hills, hill slides and river valley formations (incised meanders and benches).High hills are generally conical shaped peaks ranging above 1500m. They also become overhanging scraps near the Thrust faults. The high hill landforms generally behave like watersheds of the major tributaries of the Alaknanda, consequently rills, gullies and seasonal channels have been developed to make terrain more dissected. The vegetable cover is very scant and hill tops are necked. The hill side landforms between hill and the river valley ranging from 500 to 1500m. The hill sides generally consists of talus or screes. They have repose slopes near thrust where they are fully developed. The hill-sides have thick vegetable cover but become scant due to redundancy of landslides caused by thrust zones.

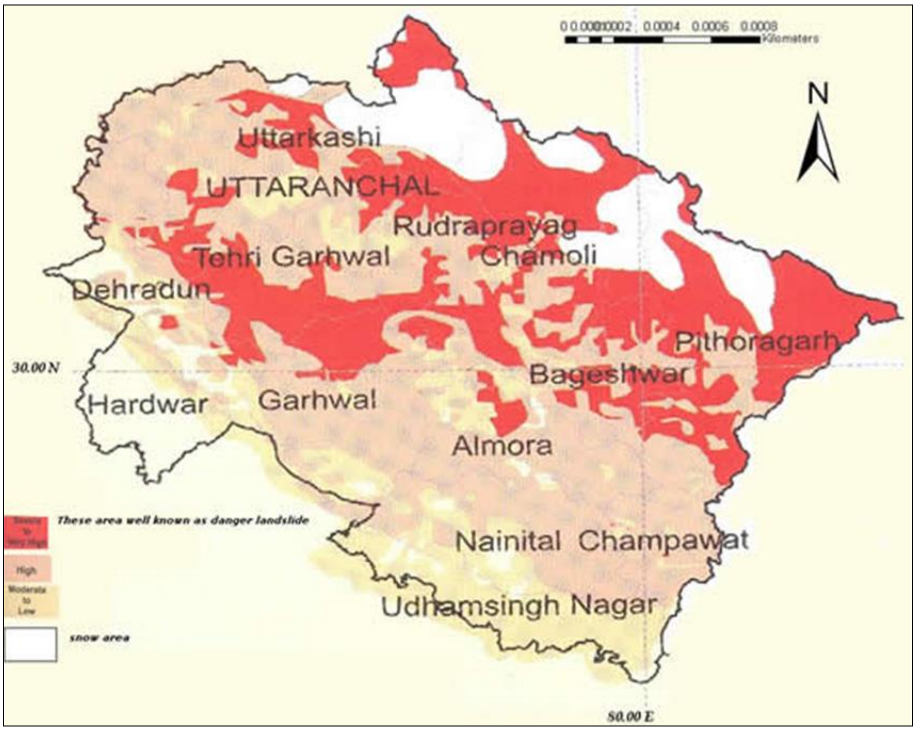

Fig 3: Landslide Zone of Uttrakahand (Source: Govt. of Uttrakhand, Disaster Mitigation and Management Center)

The river valley formations consist of incised meanders, river benches of 500m and below it. The incised meanders have gentle slopes with thick vegetal cover and steep slope with scant vegetal cover. The drainage system is highly related with the geomorphological formations. The main tributaries of Alaknanda like Dauliganga, Nangakini, Pindar and Mandakini rising from the high hills isolated watersheds contribute their water to the Alaknanda forming unparallel drainage. Consequently the hillside slopes have been transversely gullied and dissected. Several streams of the Alaknanda River contribute their water to it through underground passage which activates the conditions for landslides. In addition the temperate and sub-temperate conditions of the Himalayas activate weathering and under cutting action of running and ground waters of the drainage. The average annual rainfall is 150cm. thus the greater moisture content in the soil and air as observed and they are more richly causes the moistened landslides.

Table 1: Density of Landslides in Alaknanda Valley

Density of landslides per kms	Name of the villages(area)
7 to 10	Pipalkoti, Helang, Belakuchi and Chamoli
3 to 6	Hanuman-chatti, Dhak, Tapovan and Pandukashwar
1 to 3	Kaliasor and Rudraprayag

***Source*:** A geographical study of landslides in Alaknanda Valley (Garhwal Himalayas) (Sharma, 1982) [15]

Thus all these factors show that this region is prone to severe landsides (fig. 3.) and this may damage the dam structure built in landslide prone area. As we move down with river the density of landslides reduces and also stability of the Himalayas rises, thus it is more sustainable to construct dam on the lower streams of the river.

2. Earth-Quack: Entire Himalayan domain is geodynamically very sensitive and Uttrakhand lies in the zone IV and V region (fig 4) which is very high damage risk zone. In its seismicity all along the faulted zones are quite active. By active faults it is meant that horizontal or vertical movements on the faults have taken place in the geologically recent times. The snapping and slipping of rocks on faults generate shock waves and the passage of ground wave causes damage and destruction. Many of the faults and thrusts of the Himalayas have given rise to earth quacks. Intriguingly, the much faulted central sector of the Himalayan Arc-Himachal, Garhwal and Kumaon have remained seismically for quiet some time with regard to higher magnitude earthquacks.

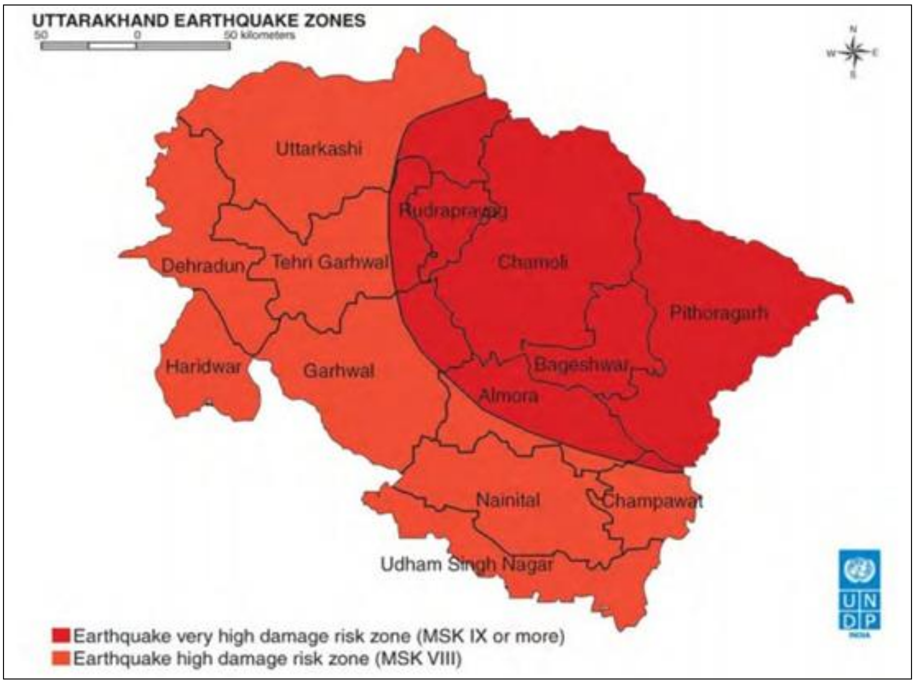

Fig 4: Earthquack Zones of Uttrakhand by UNDP (Source: Govt. of Uttrakhand, Disaster Mitigation and Management Center)

But in this region, the stresses are progressive building upside, as the sediment is being strongly pressed and prodded by the subcontinent. The Uttrakashi, Tehri and Chamoli region lying directly in this line of the ridge is in a critically stressed condition. The Srinangar Thrust crosses the terrain in NW-SW direction. And the whole mountain range repeatedly upliftment and squeezed up between the Main Boundary Thrust and Srinagar Thrust in the geologically recent times. And this can cause large scale earth quacks in this area. Thus it is not sustainable to build dams in earthquake prone areas.

3. Flash Floods: Flood has been a problem in long history of Uttrakhand. The first biggest flood of Alaknanda was in 1894, in which the famous Birahi Lake was destroyed and entire township of Srinagar was washed out. Important flood of Alaknanda in 1924 in which remnants of Srinagar were totally swept away. The biggest flood Alaknanda observed in July 1970, which washed away the Halting station, destroyed 6 motor bridges, 16 foot bridges, a road length of 30 km, 604 houses and 200 ha of standing crop. River Alaknanda is prone to flash flood, which have very high intensity, thus building of dams is not sustainable it can get washed away with these flash floods and will also add to increase the intensity of these floods and destruction will increase.

4. Global Warming: With the accelerated glacial melting the dams are likely to see huge increase in inflows initially and then highly reduced inflows in subsequent decades. This effect is likely to threaten the safety and economy of the dams being constructed.

Consequences of development of dams on river Alaknanda

Drying of the River: Due to dense allocation of hydropower projects in the study area, water released from the tail of the tunnel would enter the reservoir of another hydropower project. Thus hydro power project would cause practical drying up of the river, especially during the lean season flow period. As a result, the velocity and volume of flow would change suddenly in stretches and this would have serious implications for the aquatic ecology of the cold water fisheries of the region.

Dam Failure: As the Main Central Thrust and Main Boundary Thrust lines traverse along the entire Himalayan region, the area is susceptible to high seismic risk. And Alaknanda catchment lies in the geo-dynamically sensitive Himalayan region (Seismic zone V), thus naturally prone to disasters. Earthquakes of magnitude of 8.5 on Richter scale have been recorded in the Himalayas. It needs to be noted that the kind of developmental interventions associated with hydropower projects, serious manmade disaster due to failure of dams may occur. The reasons of the dam failure could be technical flaw in the design or extreme rain fall event, etc. However, it is beyond argument that huge destruction of life, property and environment is expected. According to the EIA guidelines of MoEF, dam break analysis for disaster management planning is required for individual projects, wherein, there can be no consideration for other dams in upstream and downstream, ignoring the cascading effects of dams proposed in a series. However, in real world situation, if a single structure is failing, that will trigger chances for failure of another structure in the downstream and so on.

Degradation of Natural Beauty: With the development of Dams fr hydropower projects, the natural flow of the river will be fragmented and would also disappear into the tunnels causing tremendous loss to the panoramic landscape of the region. Besides this, construction of Dams which is related to hydropower projects will also lead to modernization of the area and in turn will cause degradation of the natural beauty of the valley that is characterized by scattered small hamlets spread over the mountain slopes with intermittent agricultural fields and herds of domestic animals being bred by ethnic communities attired in traditional dresses. In brief, the development of dams in the region would certainly affect the tourism potential of the area.

The extremely important confluences of spiritual and historical value such as Nand Prayag (Alaknanda and Nandakini), Karna Prayag (Alaknanda and Pindar), Rudra Prayag (Alaknanda and Mandakini) and Dev Prayag (Bhagirathi and Alaknanda) of the Ganga with its various tributaries stand to be destroyed by these projects.

- **Extinction of Culture (impact on sociocultural setting of the area):** Construction of the projects will lead to an influx of outsiders – labourers and contractors in the region, and this would lead to the dilution of the culture of the pastoral communities. Further, development of dams will helping providing irrigation facility thus it will cause change in land use pattern and this may significantly affect the availability of already limited pasture land (on account of increasing number of livestock and also increase in land under agriculture) to the pastoral communities.
- **Human induced Flood:** Dams bring human induced floods, as role of dams is to store water during rainy season (mostly at the end of monsoon) these dams get filled with water upto the danger mark and under excess rainfall conditions the authority opens the gates of the dam. And this sudden release of water in large quantity leads to flood situation in the river (mainly the lower areas)
- **Submergence:** building of dams may lead to submergence nearby low lying area like all vegetations, agricultural lands, mineral deposits, existing roads or transport network in the lower valley.
- **Increase in seismicity:** Construction of big dams may increase seismicity of region because of transmission of additional heavy load due to weight of the retained water in reservoir to the strata below.

And also heavy blasting and mining operations were performed during the construction of Dam and others, vast areas became unstable. The unending pressure on the fragile ecosystems of high hill regions by indiscriminate blasting for multipurpose projects, dams and highways, accelerate the dynamic forces which are equally responsible for soil instability. The vast devastation by the recent(Oct, 1991) earthquake in Uttarkashi, particularly near to Maneri Bhali dam and adjoining areas, may be are due to the earth's dynamic processes and to human interference in these dynamic processes.

- **Change in ground water scenario:** because of detention of water in reservoir and consequent seepage of water will lead to immediate changes in ground water conditions.
- **Change in physiochemical parameters of water:** mainly the flow speed, transparency, temperature, and dissolved oxygen of dam's water shall change. Thus planktonic and benthic life and fisheries of river in dam will be depleting.
- **Siltation:** Reservoirs may get silted quickly because Alaknanda brings large amount of sediment load.

The fate of the five holy prayags: The holy Devprayag would be submerged under at least 10 m high standing water of Kotli Bhel 2, the holy Rudraprayag would remain submerged under water from the proposed big 860 MW storage project at Utyasu. The holy Karnaprayag

Fig 5: Hydro Electric Projects on River Alaknanda (Source: www.sandrp.in)

would have the proposed storage project Padli along the Pinder River on the one arm and the 160 MW Karnaprayag hydropower project on the other arm. The Nandprayag is likely to remain dry in non-monsoon months due to the proposed 141 MW Nandprayag Langasu Hydropower project, just upstream of the prayag. Vishnuprayag is already impacted due to the existing 400 MW Vishnuprayag project, but its fate would be worse if the proposed 520 MW Tapovan Vishnugad project on Dhauli Ganga River comes about.

Table 2: Salient features of the proposed hydropower projects in Alaknanda catchment

Project name	Developer	Installed capacity(MW)	Location of Dam Lat & Long		Dam/ barrage height (m)	Submergence area (ha)
Malari–Jhelum	THDC	55	30°40′ 54.7″	79°53′4.5″	24.5	NA
Jhelum–Tamak	THDC	60	30°38′45″	79°49′57.5″	24.5	13.9
Tamak–Lata	UJVNL	280	30°36′00″	79°47′00″	12	NA
Lata–Tapovan	NTPC	171	25 km u/s of joshimath	NA	NA	NA
Tapovan–Vishnugad	NTPC	520	30°33′51″	79°33′46″	22	10
Vishnugad–Pipalkoti	THDC	444	30°30′50″	79°29′30″	65	24.5
Vishnuprayag	JPVL	400	30°40′10″	79°30′35″	NA	NA
Alaknanda	GMR Energy Ltd	300	30°43′09″	79°29′49″	36	3.74
Bowala–Nandprayag	UJVNL	300	Near Birahi village	NA	5	NA
Nandprayag–Langasu	UJVNL	141	30°19′30″	79°18′20″	15	NA
Srinagar (Supana)	Alaknanda Hydro Power Company Ltd	330	30°23′47″	78°22′20″	66 (concrete gravity dam)	NA

Source: Feasibility reports of the hydropower projects. NA stands for not available

Fig 5: Site of Tapovan Vishnugad dam under construction

Table 3: Likely Primary Adverse Environmental and Social Impacts of the Tapovan–Vishnugad HEP

Issue/Feature	Impact	Extend	Duration
Hydrology	Reduced river flows between barrage and tailrace outlet Decline in river water quality	Along an 18 km stretch of river	Permanent
Aquatic ecosystems	Altered river ecosystem Prevention of upstream fish Movement	11 km Dhauliganga, 7 km Alaknanda pondage inundation are Up to 90 km of the Dhauliganga plus tributaries	Permanent
Land resources	Loss of agricultural and forest land	144.6 ha total land conversion	Permanent
Social	Resettlement of households	57 households, predominantly self-relocated	Permanent

Source: WAPCOS. 2004. EIA Study for Tapovan–Vishnugad Hydroelectric Project. Gurgaon

The Alaknanda River is becoming a highly regulated water resource that is likely to have several HEPs installed over the next 10 years (fig. 5). The two HEPs that are most likely to increase or mitigate the impacts created by the Tapovan–Vishnugad HEP are the operating Vishnuprayag HEP and the proposed Vishnugad–Pipalkoti HEP, both on the Alaknanda River. The 400 MW Vishnuprayag HEP has a 14 m high barrage about 16 km upstream of the Dhauliganga confluence, with a tailrace outlet 1–2 km below the confluence. This project is dewatering the intermediate 18 km section of the Alaknanda River in the dry season. The proposed Vishnugad–Pipalkoti HEP dam, 2.5 km downstream of the Project's tailrace outlet, will inundate the Alaknanda to within 1 km of the project tailrace outlet.

Table 4: Environmental and Social Impacts of the Alaknanda HEP (Joshimath)

Issue/Feature	Impact	Extend	Duration
Hydrology	Reduced river flows between barrage and tailrace outlet Decline in river water quality	5.8 km downstream of the barrage site would become dry during the lean season	Permanent
Aquatic ecosystems	Altered river ecosystem Prevention of upstream fish movement	Will not harm exotic species of fishes	Permanent
Land resources	Loss of agricultural and forest land (Submergence of land)	7.53 ha of total agriculture land came under this project and 2.27 ha forested area will submerged	Permanent
Social	Resettlement of households	12 families affected(227 family members)	Permanent

Source: CISMHE, Environmental Impact and Management Programme of Alaknanda Hydro Electric Project, Uttrakhand.

Impact Assessment and Evaluation of Alaknanda Hydro Electric Project (HEP)

The environmental impacts of the proposed Alaknanda H.E. project are being forecast in light of the activities that would be undertaken during the construction of barrage, coffer dam, drilling and blasting during tunneling for head race tunnel, roads, construction of permanent and temporary housing and labour colonies, quarrying for construction material and dumping of muck generated from various project works and other working areas. The likely impacts are:

Impact on Terrestrial Ecosystems: Habitat disturbance, degradation, fragmentation and destruction due to construction activities would lead to disruption of flora and fauna. The proposed area to be submerged by the proposed project is about 2.27 ha, which is mainly under forest. The vegetation in the vicinity of the proposed project area is scattered composed of Temperate mixed coniferous and scrub forest. On the right bank, there are trees of Betula alnoides, Ilex excelsa, Rhododendron arboreum, Taxus baccata and Viburnum grandiflorum and shrubs like Berberis umbellata, Cotoneaster rotundifolius, Rhododendron campanulatum, Rosa macrophylla, Sorbus tomentosa, Viburnum cotinifolium, etc. Herbaceous flora is comprised of Anaphalis busua, Arabisamplexicaulis, Cardamine impatiens, Cerastium glomeratum, Corydalis cornuta, Epilobium palustre, Geranium wallichianum, Imperata cylindrica, Potentilla cuneata, Sedumewersii, etc. The reservoir would hamper the movement of wildlife. The creation of a barrage across the river and formation of a reservoir would result in the change of habitat and would lead to fragmentation of habitat. This reservoir will function as a physical barrier, which comes in the way of animal migration and dispersal. The proposed project activities like drilling, blasting, etc. would lead to increased noise levels in the area, which may cause disturbance to the wildlife in the area. The construction of the project facilities would involve deforestation. Thus the danger of erosion and disturbance to hill slopes is high.

Impact on Aquatic Ecosystems: The most obvious impact of hydro-electric projects is the upstream inundation of terrestrial ecosystems and, in the river channel. They also alter the downstream flow regime. Reservoirs reduce flow velocity and so enhance sedimentation. The rate at which sedimentation occurs within a reservoir depends on the physiographic features and land-use practices of the catchment, as well as the way the barrage is operated. It is estimated that between 0.5% and 1% of the storage volume of the world's reservoirs is lost annually due to sediment deposition. Downstream of the barrage, reduction in sediment load in the river can result in increased erosion of river-banks and beds and loss of floodplains. Reservoir flushing (i.e. the selective release of highly turbid waters) is a technique sometimes used to reduce in-reservoir sedimentation. The proposed project would result in submergence of 2.27 ha and it may lead to adverse changes in the river ecosystem. However, for mitigating the downstream impacts, it is mandatory to maintain at least 10% of the lean season flow in the river. The river stretch of about 5.8 km downstream of the barrage site would become dry during the lean season, therefore, the project authorities have been advised to maintain sufficient amount of discharge during the lean period to maintain and sustain the aquatic ecosystem functions in this stretch. The likely impacts on the water quality arise from inappropriate disposal of muck, effluents from crushers and other sources and sewage from labour camps and colonies. The muck will essentially come from the road-building activity, tunneling and other excavation works. The unsorted waste going into the river channel will greatly contribute to the turbidity of water continuously for long time periods. Therefore, in order to avoid any deterioration in water quality and subsequent changes in the aquatic biota, project authorities propose to have a proper sewage disposal system in and around various labour colonies to check the discharge of waste and refuse into the river. And this will not only deterioration water quality but will lead to subsequent changes in the aquatic biota. The degradation in water quality will mainly arises from discharge of waste and refuse into the river channel by the labour colonies and other temporary human habitations.

Geo-physical Impacts:_The area lies in the seismically active Zone-V of the seismic zoning map of India and has witnessed micro-seismic activity. As it is evident that the project area is very close to seismically active zone in the vicinity of MCT. Therefore, it is essential to adopt suitable seismic coefficient in the design_for various appurtenant structures of the project. Geological disturbance due to blasting, excavation, Soil erosion as cutting operation disturbs the natural slope & lead to land slides, Interruption of drainage pattern, Disturbance of water resources with blasting and discriminate disposal of fuel and lubricants from road construction machinery, Siltation of water channels/ reservoirs from excavated debris, Effect on flora and fauna, Air pollution due to dust from debris, road construction machinery, etc. Therefore, most of the muck is proposed to be dumped in an environmentally sound manner at pre-identified locations.

Impact on Human Ecosystem: the quantum of human population migrating from other areas is greater than the local human population in the area it would result in demographic changes and other repercussions that follow. Since the migrant workforce is generally from the different regions, diverse ethnic and cultural backgrounds and value systems, they are bound to affect the local socio-cultural and value systems. In addition, these migrants might be the probable carriers of various diseases not known so far in the region resulting in health risk for the local population. The threat of habitat disturbance, degradation and fragmentation may not only come from the constructional activities, but from the large labour population that is generally employed in such developmental projects. The presence of human population in large numbers in such areas is known to exert tremendous pressure on the natural ecosystems around the project activity sites.

Some positive impacts like availability of jobs, electricity in rural areas, increase in road connectivity and eco-tourism are anticipated on the socio-economic environment of the local people of villages of project area during the project construction and operation phases.

Kotlibhel HE Project (Stage 1A)

Kotlibhel HE Project (Stage 1A) has run of river type dam with Installed capacity of 195 MW (3×65).The height of Dam is 82.5m.This project is developed by National Hydro Power Corporation Ltd. The development of this project has submerged 217.629 ha of area and 92 percent of the total land acquired for the project is the forest-land. Environment Impact Assessment (EIA) of the Kotlibhel HEP Stage1A, project is done Hemwati Nandan Bahugana Garhwal University, Srinagar (Garhwal), Uttakahnd. EIA has serious methodological flaws; the EIA lacks a scale and valuation of the significance of the environmental impacts. The baseline information is incomplete with regards to the areas directly and indirectly affected by the project. The baseline information does not provide the quantitative information about the population density of wildlife species that would be affected present directly or indirectly by the project.

Kotli Bhel Hydroelectric Project (Stage 1B)

Kotlibhel HE Project (Stage 1B) has concrete gravity type dam with Installed capacity of 320 MW (4×80).The height of Dam is 70.5m.This project is developed by National Hydro Power Corporation Ltd. The development of this project has submerged 550.619 ha Out of which 496.619 ha is reserve forestland. That means 90 percent of the area required for the project is the forestland. The Environment Clearance was granted by Ministry of Environment and Forest by its order dated 14/08/07 for this project. EIA of this project analyses that the very origin of Ganga, at Devprayag would be permanently under about 10 m high water column. The area is rich in biodiversity –both floral and faunal. 90% of the area required for the project is the forestland. Butterflies of Nymphalidae and Papilionidae families are more likely to be affected by the proposed project. The impact is serious as these butterflies are host specific and the disappearance of host can lead to the extinction of these creatures. Along with this the life cycle of other life forms may be disturbed and can lead to various unexpected changes. There is also a greater chance of change in local climate: high humidity and increase in temperature which will breed vectors like mosquito's which are a threat to humans as well as a danger to fauna (Second Report on EIA Response Center (ERC), 2008). As per reports of Otter expert S.A Hussain of the Wildlife Institute of India, The entire Alaknanda Valley is suitable for Smooth Coated Otter habitation: "Along the entire Alaknanda, fallen rocks and boulders, deep crevices and caves provide suitable den sites for otters". The IUCN Species Survival Commission, Otter Action Plan, 2000s have opined that "Otters are not getting adequate attention while conducting EIAs. Trout and species of Mahseer are the two fish species threatened by the project. It is therefore important that along with biodiversity, the ecological significance of the fish species and aquatic biodiversity is also assessed, which unfortunately has not been done in the EIA Report. Thus The Supreme Court has agreed to the suggestions of the Central Empowered committee and the project has been sent back to the Forest Advisory Committee for reconsideration of forest clearance issued under the Forest Conservation Act, 1980.

Suggestive Measures Should Be Taken For Sustainable Development of Dams

1. **Small size:** Dams should be small sized; it will fulfill the irrigation requirement of the region and also electricity of the local areas. Benefits of small size dams is that it will lead to less submergence of nearby area, less forest cover of agriculture land will destroyed, negligible impact on environment, less or negligible reduction in flow and velocity, less people will be displaced, less load of water retained in the reservoir because of small size, thus will not influence the seismicity of the region.
2. Conservation and preservation of natural ecosystems and areas which may hold potentially important species from the conservation and/or economic significance.
3. Preservation of natural habitats in the catchment.
4. Special efforts for in situ or ex situ conservation of critical/ important plant/ animal species.
5. To improve habitat conditions by taking up afforestation and soil conservation measures
6. To create awareness regarding conservation and ensure people's participation in the conservation efforts.
7. Reduce and mitigate of noise so as to cause as little disturbance to the animals by using well maintained/new equipment that produce lesser noise than old and worn out one at the work sites. The combustion engines are required; they will be fitted with silencers. The traffic (trucks, etc.) used by the project works will be managed to produce a smooth flow instead of a noise producing stop and start flow. While clearing the land of vegetation for any project work, the project authorities will ensure that the work area has sufficient layers of tree cover around it. It will act as an effective noise absorber. It will be better not to have bigger trees lopped or cut around the periphery of the site. The tree layer will act as buffer zone and these are known to cut off noise by about 3-12 dB at a site depending upon the density of vegetation. These measures will be planned in advance and well before starting operation at any site.
8. Rehabilitation of degraded slopes and landslide prone areas.
9. Fisheries management by the construction of small check dams across the river. In order to the maintenance of pools small check dams are needed in the rivers. At least 4 dams would require in the 12 km stretch of the river. The check dams would be supplied through regular water supply from the mandatory release of water (10%) from the dam and other small tributaries.
10. Sufficient precautions should be taken for developing proper system for the sewage treatment from the colonies of labours and workers, solid waste disposal and cleaning of the colony area. For these septic tanks and soak pits shall be provided for individual dwellings. There should be proper water facilities to these workers for drinking and other purposes. The project authority should also take care to keep the local villages clean and provide various facilities related to water and sanitation.
11. **Disaster & Hazard Management Plan:** The Himalayan valleys are subject to the occurrence of apparently sudden calamitous events. These events, in fact, represent the climax of the interaction of numerous independent or unrelated natural phenomena, whose final action is synchronized to produce a sudden and major catastrophic effect. For example, an earthquake represents the culmination of a sequence of tectonic events which trigger seismic action. The seismic waves may lead to the occurrence of significant geo-morphological changes and create conditions for massive landslides and trigger snow or debris avalanches. These events could set the stage for a temporary lake formation in a river valley. Such a lake will have potential of creating a catastrophic flood downstream in eventuality of overtopping. Similar effect could be generated by a cloud burst in any of the sub-watersheds. Some of the potential phenomena and sites, where catastrophic conditions are foreseen in Alaknanda valley, are glacial lakes, cloud bursts – flash floods and avalanche hazard mitigation. The methods like structural control or afforestation arrests the creep and glide

motion of snow on slopes, and thus avalanches too, artificial triggering helps to bring down the avalanches before they reach stupendous proportions. The latter method is relatively cheap. The passive methods include: a) Awareness, b) Forecasting and c) Safety and Rescue.

12. **Measures taken by government:** on July 16, 2010 The Union environment and forests ministry's Forest Advisory Committee (FAC) has decided not to give forest clearance to any of the proposed projects until the National Ganga River Basin Authority conducts a cumulative impact assessment study of all proposed dams. Uttarakhand has planned to build 300 small and large dams on the various tributaries of the Ganga to tap the hydel potential of the state. The FAC has decided not to allow even one dam to proceed unless the total impact of all proposed dams is studied.

Conclusion

Construction of large dams on river Alaknanda are not sustainable because Alaknanda flows in the Himalayan region which is geo-tectonically very active and prone to seismic activites which causes landslide, earthquack and flash floods in this area occasionally. Development of dams in Alaknanda basin will negatively affect the flora and fauna, climate, human ecosystems and it will also influence the geo-physical setting of this region. Thus for sustainable development of dams some measures should to be taken. And the most important one is that dams that are being built should be small in size, that will met the power requirements and irrigation requirements with negligible adverse impact on flora and fauna, climate, human ecosystems and geo-physical setting of this region.

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